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A Design for an Ozone Reactor with Different Electrode Configurations

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***Abstract**: Water contamination from domestic and industrial sources is one type of environmental pollution that is on the rise. Three key issues need to be addressed in order to overcome this: environmental management and policy, societal environmental awareness, and the use of suitable technologies to combat pollution. By developing, constructing, and implementing suitable technology to create an Ozone reactor with high-voltage corona discharge plasma technology, this study aims to address the issues of environmental pollution. A corona discharge between each configuration's high-voltage electrodes ionizes the oxygen flowing through the reactor, producing plasma and ozone. Drink samples are used to determine the fading colors of wastewater, which are getting progressively softer over the course of numerous waste treatment cycles in the Ozon reactor. Based on the study of four Ozone reactors, the reactor Ozone configuration with spiral-cylinder electrode with DBD yields the most effective waste water treatment.*

***Keywords**: wastewater, corona discharge, electrode configuration, ozone reactor*

I. Introduction

The complexity of environmental pollution has increased. Three key issues need to be addressed in order to combat pollution: environmental management and policy, environmental consciousness among all societal segments, and, finally, the appropriate application of technology to combat different types of pollution. Although there were few issues that would arise from the usage of technology, pollution processing technology in Indonesia was not given any serious attention during this time. As Indonesia's industry continues to expand, it is imperative that the right technology be chosen and implemented right away to address environmental issues. Many different types of materials are typically employed in industrial production processes. Heavy metal-containing water pollution in urban, agricultural, and industrial contains several organic chemicals such as dioxins, phenols, benzene, PCBs, and DDT, as well as Cu, Hg, and Zn. At the moment, wastewater treatment systems are insufficient to lower water pollution. Efforts will be made to apply plasma technology to address the issue of water pollution, which could endanger environmental degradation and the creation of oxygen in water. The creation of plasma through high-voltage corona discharge happens when electrodes are placed correctly inside a plasma reactor chamber. The production of corona discharge can be achieved through several electrode configurations including needle-plane and wire-cylinder and spiral-cylinder and dielectric barrier discharge. An electrode discharge produces plasma inside reactors by transforming oxygen into ions while it circulates through between electrode elements. Plasma production amounts in the Ozone reactor depend on the type of high-voltage electrodes and their form along with their distance from these electrodes as well as the high-voltage source. The development process for the Ozone reactor follows a comparison of available electrode components and design equipment. A high voltage along with a high frequency pulse generator powers the Ozone reactor. The combination between a flyback converter and a high voltage pulse generator will produce stronger electrical output pulses. At the Ozone reactor the electrode configuration change leads to enhanced corona discharge thus producing more plasma and ozone concentration. The production process generates sufficient ozone together with plasma which can be utilized for wastewater purification methods.

II. Research Method

This research employs four distinct electrode arrangements within its Ozone reactor design including wire-cylinder electrode and spiral-cylinder electrode as well as wire-cylinder electrode with Dielectric Barrier Discharge (DBD) and spiral-cylinder electrode with DBD. The fourth ozone reactor can function with a high voltage impulse source reaching 20 kV. Through the implementation of a flyback converter the generator can generate high voltage

high frequency pulses which feature a voltage range from 0 to 20 kV. The negative electrode takes the form of a cylindrical tube that serves as ground while wire functions as the positive electrode in a wire-cylinder electrode-based corona discharge plasma reactor. The plasma reactor chamber displays a tube shape with dual lids installed on its right side.

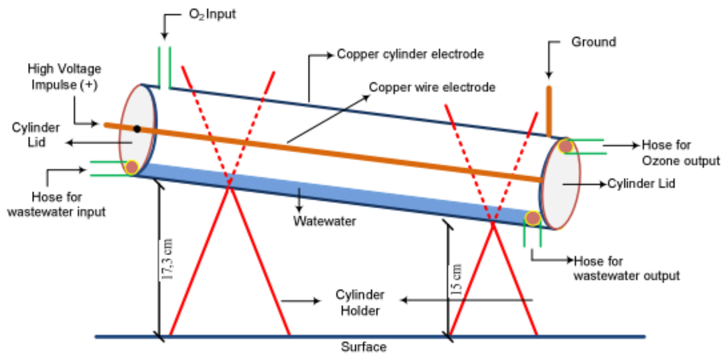
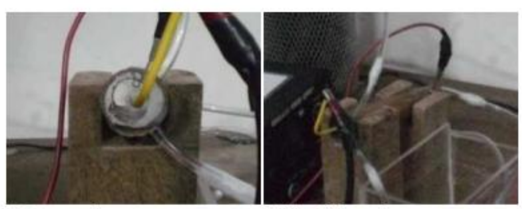


Fig 1: Ozone reactor design with a wire-cylinder electrode arrangement

A straight copper wire of 24 cm in length and 4.8 mm in diameter forms the positive electrode. The source of the high voltage impulse is directly connected to the positive electrode wire, which is placed in the centre of the cylinder tube. A cylindrical copper tubular pipe of 4.8 cm in length, 32 mm in diameter, and 1 mm in thickness was employed as the negative electrode (ground). A connection system through wires is present on the tubes exterior to allow a direct ground connection of the negative terminal from the high voltage impulse generator source. A four-point hole exists on the cylinder body of the negative electrode while two hoses service reactor input and output by serving oxygen and wastewater as inputs alongside ozone and wastewater as outputs. A distance of 14 mm exists between the electrode wire and electrodes during oxygen and waste flow and the corona discharge process in these reactors. The wire-cylinder electrode geometry positions at 20° slope angle when serving as a plasma reactor waste processor through the use of a buffer tube holder with first leg at 12.4 cm and second leg at 21 cm height. The purpose of the buffer tube holder controls the wastewater entering the corona discharge plasma reactor system.



(a) Front view (b) Side view

Fig 2: Wire-cylinder ozone reactor configuration Wire-cylinder ozone reactor configuration

Spiral-Cylinder Electrode Ozone Reactor Configuration: The spiral-cylinder electrode geometry comprises a coiled positive electrode alongside a cylinder tube operating as negative electrode (ground) following wire-cylinder electrode arrangements known from corona discharge plasma reactors. The plasma reactor chamber with spiral-cylinder shape consists of a cylindrical tube enclosed by two right and left acrylic covers. The spiral electrode comprised twisted copper wire with dimensions 9 cm x 7 mm diameter from wires with a 3 mm diameter. The high voltage impulse passes through the spiral electrode that sits at the middle part of the cylinder tube directly. The negative electrode made of 23 cm long copper tubular pipe served as the ground connection. The tubes feature external wires that serve to ground the negative terminal of the reactor using the high voltage impulse generator's source directly. The system contains two ports for oxygen and wastewater purpose while featuring two discharge ports for ozone output and processed wastewater. A four-point hole exists in the cylinder body functioning as the negative electrode body where a hose connects with input and output points to the reactor. The measures of corona discharge and oxygen flow together

with wastewater processing depend on the distance between reactor cylinders' electrodes which amounts to 12 mm between spiral electrodes.

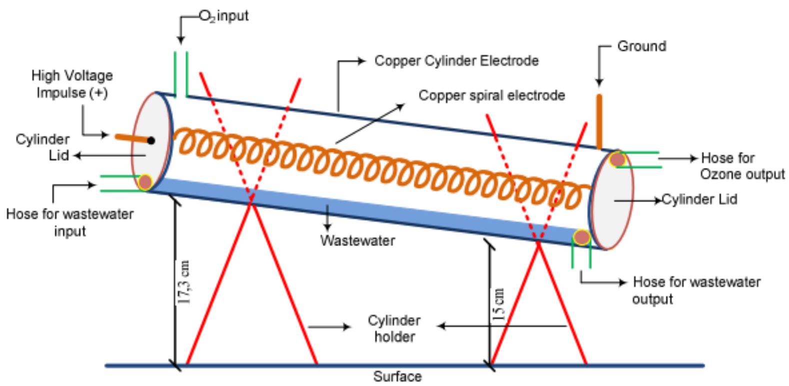


Fig 3: Ozone reactor design using an electrode spiral-cylinder arrangement

The corona discharge plasma reactor with spiral cylinder electrodes functions in the same way as in the previous design to handle wastewater treatment. The tubular chamber depends on a 20° incline for its setup position. The device rests upon a buffer tube holder that contains two legs positioned at different heights where one leg reaches 22 cm while the other stands at 14 cm.

(a) Front view (b) Side view

Fig 4: A spiral-cylinder-shaped ozone reactor.

Dielectric Barrier Discharge (DBD) Ozone Reactor with Spiral-Cylinder Electrode Setup: An electrode wire acts as the positive element in the wire-cylinder electrode configuration with DBD plasma reactor design and plasma formation occurs between this electrode and a cylindrical negative electrode which operates as the ground and uses a dielectric material as the barrier discharge. The plasma reactor chamber has tube shape design which includes acrylic lids placed on both right and left sides.

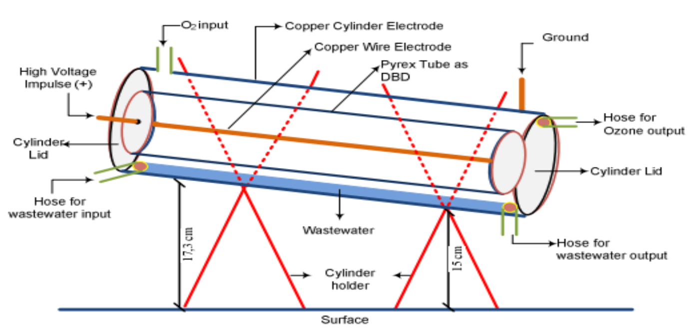


Fig 5: Ozone reactor design utilising a wire-cylinder and DBD electrode setup

Copper wire positive electrode in the shape of a straight wire, measuring 16 cm in length and 1.9 mm in diameter. A cylindrical copper tubular pipe of 16 cm in length, 32 mm in diameter, and 4 mm in thickness was employed as the negative electrode (ground). The wire connections on the outside of the tubes are used to connect the reactor's negative terminal to ground straight from the high voltage impulse generator's source. A dielectric material consisting of a 22-cm-long, 16-mm-diameter Pyrex glass tube with cylindrical electrodes positioned between the wire electrode. A barrier function of Pyrex tube protects both positive electrode and negative electrode wire-cylinder from damage. The positive electrode faced the negative electrode due to the dielectric layer that covered the glass pyrex surface. The hose connects with both reactor inlets and outlets at the body of the cylinder which acts as the negative electrode where two intake ports accept oxygen and wastewater while two emission ports release ozone along with wastewater. The precise distance of 18 mm exists between the wire electrode and the cylinder electrodes because of corona discharge phenomena affecting oxygen flow and wastewater flow rate. The corona discharge plasma reactor utilized for wastewater treatment includes wire-cylinder electrodes that implement a DBD positioned at a 10° angle. Two different height leg structures combine to form the buffer tube holder where the first leg reaches 19 cm and the second leg extends to 18 cm.

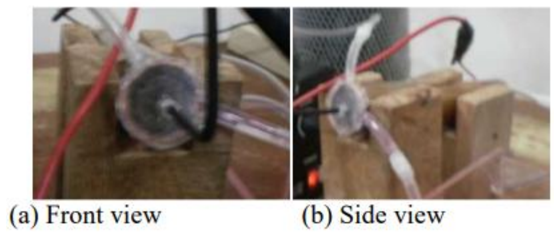


Fig 6: DBD wire-cylinder ozone reactor configuration

Ozone Reactor with Spiral-Cylinder Design and Dielectric Barrier Discharge (DBD): A spiral shape functions as the positive electrode when combined with a cylindrical tube operating as the negative electrode together with a dielectric material that presents the barrier discharge across both electrodes. Inside the plasma reactor chamber a cylindrical tube exists along with acrylic lids at precise positions on the right and left sides.

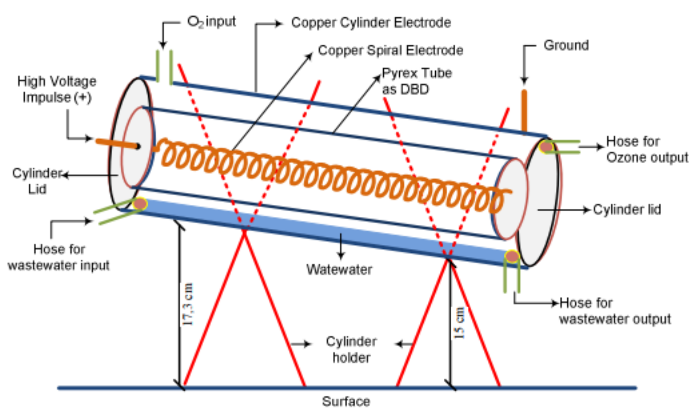


Fig 7: Design of ozone reactor using DBD electrode arrangement and spiral-cylinder

The positive electrode is a 17 cm long spiral electrode constructed of copper wire with a 2 mm diameter that has been twisted into a 5.1 mm diameter spiral. The high voltage impulse source is directly connected to the spiral electrode, which is positioned in the center of the cylinder tube. A cylindrical copper tubular pipe of 16 cm in length, 18 mm in diameter, and 4 mm in thickness was employed as the negative electrode (ground). The wire connections on the outside of the tubes are used to connect the reactor's negative terminal to ground straight from the high voltage impulse generator's source. A dielectric substance in the shape of a tube is positioned between the spiral electrode and cylindrical electrode. Pyrex glass tube measuring 18 cm in length and 9 mm in diameter. The purpose of the Pyrex

tube is to act as a barrier between the wire cylinders for the positive and negative electrodes. As a result, the positive electrode was facing the negative electrode due to the dielectric layer covering the glass pyrex surface. The cylinder body, the negative electrode body, has a four-point hole on it with a hose attached to the reactor's input and output. There are two inlets for the entry of oxygen and wastewater, and two outlets for the emission of ozone and wastewater. A gap of 8 mm is placed between the spiral and cylinder electrodes to allow for corona discharge, oxygen flow, and wastewater flow in the reactors. With the aid of a buffer tube holder with two legs, one at 12 cm and the other at a 22-cm buffer, the corona discharge plasma reactor, which is used to treat wastewater, is positioned inclined 10° with a spiral-cylinder electrode and DBD.

(a) Front view (b) Side view

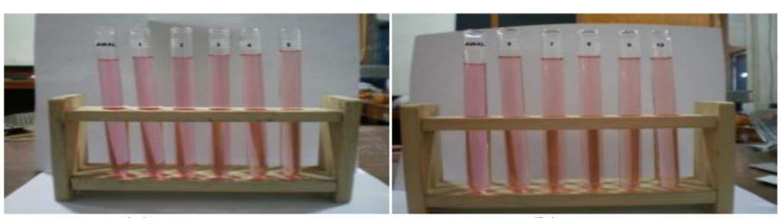
Fig 8: DBD spiral-cylinder ozone reactor configuration

III. Result and Analysis

High voltage measurement together with corona discharge plasma technology that processes soft drink industry wastewater serves as testing and analysis equipment. The testing of the plasma reactor relies on color fading detection methods to identify ozone creation. Each ozone reactor received color-faded wastewater that underwent evaluation. The experiment uses wastewater made of 75 ml red soft drink diluted with 750 ml water in the 2:30 ratio. Pure oxygen acts as a part of the processing at the Ozone reactor when wastewater samples enter. The Ozone reactor test's wastewater processing settings are as follows: • The input impulse voltage is 25 kV. • Input of wastewater stream rate = 40 ml/min • Input of oxygen flow rate = 4 L/min.

Ozone Reactor Testing Using Wire-Cylinder Electrode Setup: This procedure uses the source voltage from a high voltage impulse generator to test a plasma reactor with a wire-cylinder layout. The wire-cylinder ozone reactor is undergoing a 15-cycle process of wastewater color fading, with an average duration of one hour and ten minutes per cycle, according to the testing procedure. The wastewater process comparison findings on an Ozone reactor with a wire-cylinder electrode arrangement are shown here.

Fig 9: Ozone reactor test using a wire-cylinder electrode arrangement



(a) (b)

Fig 10: Outcome of the wastewater treatment procedure on the wire-cylinder Ozone reactor

The results show that the length of wastewater processing at the high-voltage ozone reactor using wire-cylinder configuration directly correlates to enhanced wastewater color reduction. As shown in Figure 10 each wastewater treatment cycle produces additional color fading thus leading to increased color fading in wastewater as treatment cycles increase.

Fig 11: Ozone reactor test using a spiral-cylinder electrode setup

Ozone Reactor Testing Using a Spiral-Cylinder Electrode Setup: Using the source voltage from a high voltage impulse generator, the following procedure is used to test a spiral-cylinder plasma reactor: As a result of testing a spiral-cylinder ozone reactor, wastewater color fading is being carried out in a 0-cycle procedure that takes an average of 47 minutes each cycle. The wastewater process comparison results using an Ozone reactor with a spiral-cylinder electrode structure are as follows:

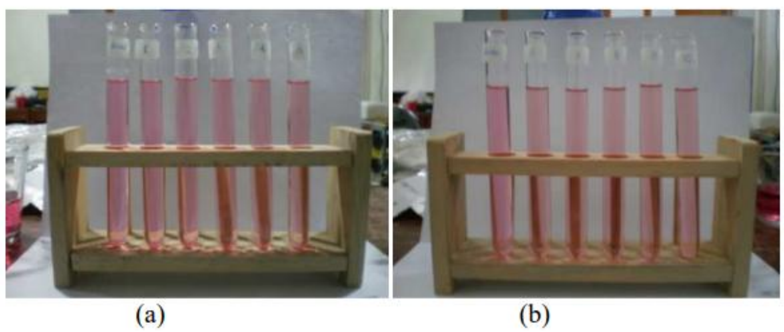


Fig 12: Outcome of wastewater treatment on a spiral-cylinder-shaped ozone reactor

The results demonstrate that when operating the high-voltage ozone reactor at high doses with spiral-cylinder construction the treatment process duration directly impacts wastewater color fading. The number of processing cycles used in wastewater treatment determines the amount of fading in the wastewater as shown in Figure 12.

Testing of an Ozone Reactor Using a Dielectric Barrier Discharge Electrode Configuration and Wire-Cylinder: Using the source voltage from a high voltage impulse generator, the following procedure is used to test a plasma reactor with a DBD wire-cylinder configuration:

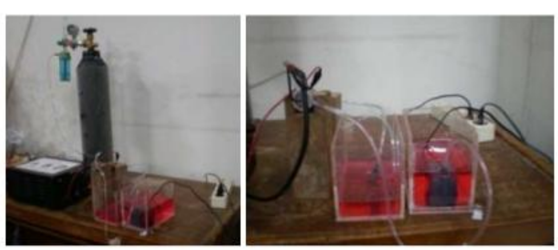
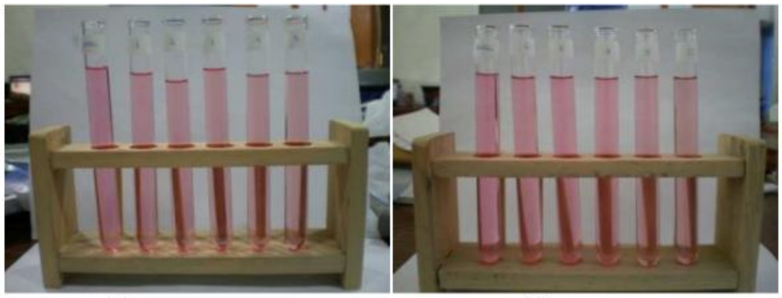


Fig 13: Ozone reactor test using a DBD wire-cylinder electrode setup

The DBD wire-cylinder Ozone reactor is undergoing a 10-cycle process of wastewater color fading, with an average length of one hour for each cycle, according to the testing procedure. The wastewater process comparison results for the Ozone reactor with the DBD wire-cylinder electrode design are as follows:



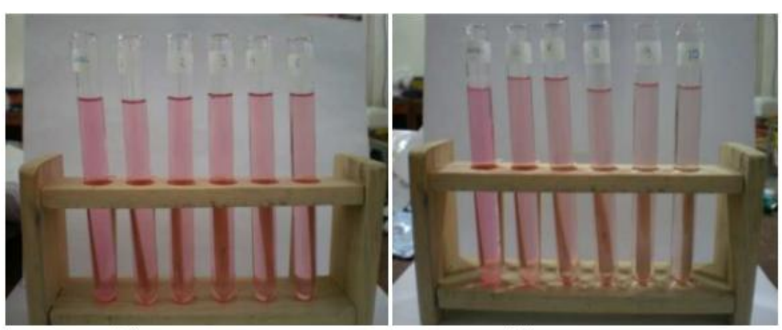
(a) (b)

Fig 14: Outcome of wastewater treatment on an Ozone reactor using a DBD wire-cylinder setup

It is evident from the findings of wastewater color fading by ozone produced at the high-voltage ozone reactor with DBD wire-cylinder configuration that the longer the wastewater treatment process, the more the wastewater's color fades. Figure 14 illustrates the occurrence of color fading gradients from cycle to cycle, meaning that the more processing cycles used in wastewater treatment, the more color fading there will be in the wastewater.

Ozone Reactor Testing Using a Dielectric Barrier Discharge Electrode Configuration and a Spiral-Cylinder: The source voltage from the high voltage impulse generator was used to test the plasma reactor with the DBD spiral-cylinder layout. According to the testing procedure, a DBD spiral-cylinder ozone reactor is tested for color fading of wastewater using a 10-cycle process with an average duration of 43 minutes each cycle. The wastewater process comparison findings on an Ozone reactor with a DBD spiral-cylinder electrode design are shown below.

Fig 15: Ozone reactor test using the DBD spiral-cylinder electrode setup



(a) (b)

Fig 16: Outcome of wastewater treatment in an Ozone reactor using a DBD spiral-cylinder design

The results of observing wastewater via a color fading process by ozone created at the high-voltage ozone reactor with DBD spiral-cylinder configuration show that the wastewater's colour fades more with the length of the wastewater treatment process. Figure 16 illustrates the occurrence of colour fading gradients from cycle to cycle, meaning that the more processing cycles used in wastewater treatment, the more colour fading there will be in the wastewater.

Comparison of Ozone Reactor Test Results: By comparing the wastewater treatment results following the tenth cycle of the testing procedure, a comparison of the results may be obtained based on the test results of four Ozone reactors in their electrode configuration. The outcomes were as follows.

Fig 17: Comparative analysis of each high-voltage Ozone reactor's tenth cycle of wastewater treatment

Research on the high voltage Ozone treatment of soft drinks in 10 cycles shows between the Ozone reactor with spiral-cylinder electrodes and DBD and the other three designs the spiral cylinder with DBD produced the greatest color reduction. Ozone generation within the DBD spiral-cylinder setup surpasses the production capacity of all other tested reactors consisting of various electrode arrangements. The ability of ozone to speed up fluid colour fading depends on the amount of ozone exposure which relates to the fluid properties. The wastewater receives additional ozone application when the water clarifies and the original color fades away.

IV. Conclusion

The four electrode configurations for the ozone reactor with plasma technology are wire cylinder electrode configuration, spiral cylinder electrode configuration, wire cylinder electrode configuration with DBD, and spiral cylinder electrode configuration with DBD. Every arrangement has been used for the treatment of industrial wastewater. The wastewater undergoes physical changes during treatment with an ozone reactor, resulting in a fading colour that is more distinct from the original wastewater's colour, according to the design, testing, and analysis that were conducted. When four setups are compared, the wastewater's colour fades to varying degrees. Dielectric Barrier Discharge (DBD)-equipped ozone reactors are the ones that produce the highest fading colour level in wastewater results.

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